Implementation of Directive 1999/92/EC : some concerns for the definition of ATEX zones

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Directive 1999/92/EC[1] is to be implemented within a year. It requires the determination of hazardous zones where an explosive atmosphere (ATEX) may occur. This zoning is expected to be accurate. So is to be the evaluation of effects associated with an ignition of the so defined ATEX zones. Hence, physical phenomena which are involved in the formation of ATEX, namely leak and vaporization of a flammable liquid, leak of a flammable gas, dispersion of a layer of combustible dust, must be taken into account and quantified. It is not recommended to oversize a zone, nor to design a zone having such a small volume that the effects of an ignition would be negligible.

Introduction

Directive 1999/92/EC defines minimum requirements, which every employer must apply to improve the safety and health protection of his workers potentially at risk from explosive atmospheres (ATEX).

Every employer shall assess specific risks arising from an ATEX, by taking into account (article 4):

- the likelihood that an ATEX will occur and its persistence;
- the likelihood that ignition sources will be present and become active and effective;
- the installations, substances used, processes, and their possible interactions;
- the extent of the foreseeable effects.

He must classify places where ATEX may occur into zones, on the basis of the frequency and duration of the ATEX (article 7), in accordance with the following classification (annex I):

- Zone 0 or 20: place where an ATEX is present continuously, for long periods or frequently;

- Zone 1 or **21**: place where an ATEX is likely to occur occasionally in normal operation;
- Zone 2 or 22: place where an ATEX is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

How to define ATEX zones

Effects resulting from **an** "ATEX ignition must be evaluated. These effects strongly depend on the volume of this ATEX (especially when the volume of the ATEX is large in comparison with the volume of the containment). Thus it is important to evaluate as precisely as possible the dimension of each zone where an ATEX is expected to occur.

To do so, physical phenomena which are involved in the formation of the ATEX must be understood and quantified.

Evaluation of the volume of ATEX zones

Case of an ATEX generated in free air from a pool of flammable liquid

Phenomena involved in the generation of an ATEX are as follows:

- vaporization of the liquid;
- mixing of the vapour with air.

The vaporization of the liquid produces a flow of molecules evolving from the liquid surface; this flow mainly depends on:

- the liquid temperature;
- the area of the pool;
- the heat transferred from the ground;
- the air movement above the liquid surface.

If the temperature of the liquid is not sufficient, an ATEX cannot be formed; typically, an ATEX can only occur above a liquid if its temperature is higher than its flash point.

If the air above the liquid is perfectly calm, the mixing of the vapour with air is only due to diffusion which is a very slow phenomenon. Theoretically, an equilibrium between liquid and vapour could be reached, producing a homogeneous ATEX in the whole containment. The ATEX vapour content relies on the liquid temperature. The larger the volume, the longer the time it would take to reach such equilibrium.

Actually, equilibrium conditions can hardly be met. Indeed, the air movement above the liquid (due to forced or natural ventilation) would drag vapours and dilute them in such a way that no more than an inhomogenous

ATEX could be formed at the liquid surface.

Mathematical models can calculate the following parameters as a function of liquid temperature, pool area and air speed above the liquid surface:

- the liquid vaporization rate;
- the ATEX volume and shape.

Moreover, by taking into account the value of the vapour lower explosibility limit (LEL), it is possible to calculate the air flow conditions for which a forced ventilation of the containment is able to:

- prevent the presence of any ATEX in the ventilation network;
- limit the volume of the ATEX above the liquid surface at such a level that this place would not be considered hazardous anymore.

Case of an ATEX generated from a leak of flammable gas

Phenomena involved in the generation of an ATEX from a leak of flammable gas into free air are as follows:

- discharge of the gas as a jet;
- mixing of gas with air.

The mixing of gas with air depends on the nature of the jet; according to its low or high speed, the jet may be respectively laminar or turbulent.

Jet speed mainly depends on the absolute pressure in the containment out of which the gas is leaking. If this pressure is higher than 2 bar, the jet is hypercritical and surely turbulent.

If the jet is laminar, the mixing of gas with air is only due to the diffusion, which is driven by buoyancy forces depending on the difference between air and gas densities. A light gas (e.g. hydrogen, methane) will disperse upwards, while a heavy gas (e.g. propane, butane) will disperse downwards. The movement of air close to the leak can also influence the dispersion of the gas.

If the jet is turbulent, the mixing of gas with air occurs within the jet itself. Mathematical models can calculate, as a function of the nature and the pressure of the gas and of the cross section of the leaking orifice, the following parameters:

- the gas flow;
- the distance from the leaking orifice where the LEL is reached on the jet axis;
- the volume of the ATEX.

Generally, in process buildings, a flammable gas is fed to the equipment (e.g. burner, oven) by a low pressure pipe network (e.g. pressure slightly higher than atmospheric). Gas leaks must be considered possible. However, if the network is only made with rigid elements and soldered **fittings,** the leak orifice is more likely to have a very small cross section, lower than 1 mm^2 (a leak cross section equal to that of the pipe would correspond to an unlikely catastrophic rupture of the pipe).

In such a case, if the jet does not impinge any obstacle, the LEL is reached on the jet axis **at** a distance less than 20 cm from the leak orifice and the volume of the ATEX is smaller than 1 dm^3.

Moreover, it must be pointed out that this volume remains constant, as long as the leaking gas is mixed with plain air. Indeed, a mixing with air progressively enriched with combustible gas would steadily lead to an ATEX volume increase.

Finally, the volume of an ATEX generated from a slightly pressurized source discharged into free air through a small orifice is small enough so as to be considered non-hazardous.

Case of an ATEX generated from a layer of combustible dust

The only phenomenon involved in the generation of an ATEX from the dispersion of a layer of dust is the blowing of the dust by an air flow. This flow must be strong enough to lift the dust and mix it with air.

A very thin layer is able to give rise to a large volume of ATEX. For example, if the LEL and specific gravity of the dust are supposed to be 40 $g\,m^{-3}$ and 1 $g\,cm^{-3}$ respectively, a layer having a mean thickness of 1 mm and covering an area of 1 m^2 is sufficient to form an homogeneous ATEX of 25 m^3 at LEL. It appears to be awkward to evaluate precisely the volume of the ATEX which can be generated by blowing a layer of dust.

Some concerns for the classification of ATEX zones

It is clear that the classification of ATEX zones (or zoning) is an important stage of the implementation of the Directive 1999/92/EC. Indeed, the extent of measures to be taken in accordance with the minimum requirements for improving the safety and health of workers potentially at risk from ATEX is bound to this classification.

One may think that it is safer when:

- a zone is classified at a level higher than the real one (e.g. Zone 1 or 21 instead of 2 or 22, or Zone 2 or 22 instead of non-hazardous place);

or

- the volume of a zone is oversized.

On the contrary, some examples show that such a zoning is neither safe nor recommended.

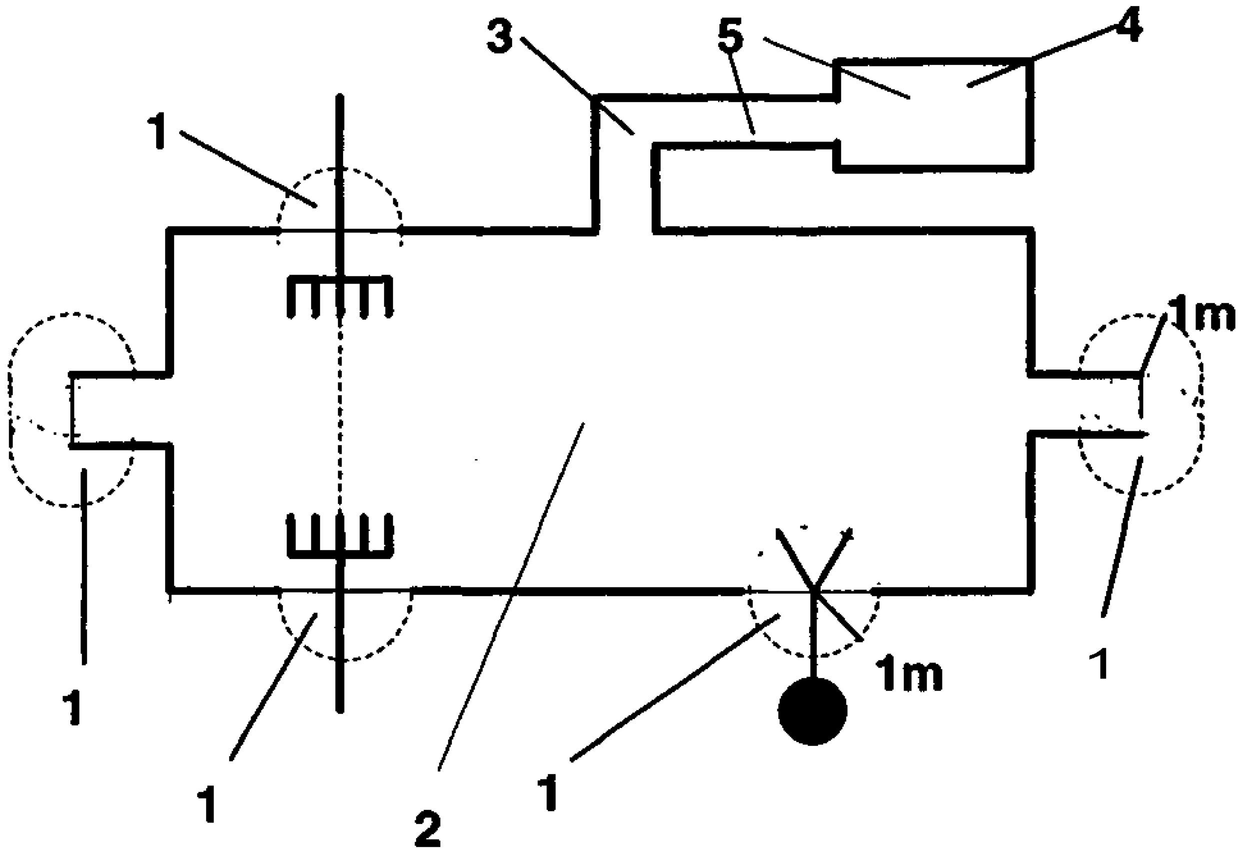
Example 1 : case of a spray booth for powder coating

In the draft standard prEN 12981: 2000[2], entitled 'Coating plants - Spray booths for application of organic powder coating material - Safety requirements', a schematic diagram (Figure 1) related to hazardous zones for an enclosed recovery system is given in normative annex A.

Figure 1 shows that the whole volume of the spray booth is suggested to be Zone 21. However, this proposal does not match the definition of Zone 21 given in the Directive.

Indeed, in normal operation, there is a forced ventilation inside the booth which drags and dilutes unused powder particles. It is therefore only in the case of a ventilation malfunction that there could be an ATEX throughout the cabin. This failure should lead one to classify the inner volume of the booth as a Zone 22 rather than 21.

Another possibility consists of fitting the booth with a secured ventilation or with an automatic safety device which switches the powder gun off whenever ventilation stops. In this case, the inner volume of the booth would then become a non-hazardous zone.



Key

1 Zone 22
2 Zone 21
3 Duct
4 Enclosed recovery system
5 Zone 20

Figure 1 Powder spray booth with enclosed recovery system

The decision to classify a place as a hazardous Zone 21 or 22 or as a non-hazardous zone is paramount since the zoning determines 'the extent of measures to be taken in accordance with annex II part A' (i.e. minimum requirements for improving the safety and health protection of workers potentially at risk from ATEX). This particular matter is stated in the preliminary note of annex I of the Directive.

If the inner volume of the booth is classified as a Zone 21 or 22, it means that, if an ignition source is present, an explosion could occur within it; then, it would develop an overpressure high enough to produce damaging effects, not only within the booth itself, but in its surroundings as well. Thus, if ignition sources cannot be under control, it would be necessary to fit the booth with a protective device (e.g. explosion venting).

Another example would be the conical spaces shaped by the powder sprays. ATEX are likely to be found within these spaces. Hence, each cone volume would be entitled to a Zone 20 or 21 classification.

The classification should be decided after taking into account the first preliminary note of annex I of Directive 1999/92/EC, which states that 'a place in which an ATEX is not expected to occur in such quantities as to require special precautions is deemed to be non-hazardous within the meaning of this Directive'. Hence, the following question has to be answered: what could be the effects of an ignition of the ATEX contained within a cone?

The volume of cones should then be compared with the volume of the whole booth in order to evaluate whether the explosion could have a significant or negligible effect so as to decide if cones should be classified as a hazardous zone (20 or 21) or a non-hazardous zone.

Example 2: case of premises

When combustible dusts, gases or vapours are processed within a premises, one has to choose what the zoning of this premises has to be. This choice is based on a thorough study of normal use or malfunctions, leading for instance to leaks of combustible material into air. Such a study is likely to split the premises into different zones with regards to the risk of creating and igniting an ATEX.

A rapid assessment could lead to a single excessive zoning throughout the premises. Such an approach does not meet the Directives expectations. Indeed, it does not highlight health and safety at work issues. It only presents a broad picture that tends to overestimate risks without pointing out the main concerns for workers.

Such an adverse implementation of the Directive is likely to be seen in industries where electrical equipment standards are beyond practices in usual industries. Petroleum industries are an example. In this particular case, it could be tempting to match zoning with existing electrical equipment categories. In doing such, one would fail in assessing workers exposure to potential ATEX.

This unwanted situation could also be seen in places where no or very few electrical/mechanical equipments are in use. In such places, a rough assessment could be favoured since it has no impact or a limited impact on new and appropriate equipment investment.

Main differences between the control of major-accident hazard involving dangerous substances Directive 96/82/EC and the 1999/92/EC Directive

The major-accident hazard control Directive 96/82/EC[3] (Seveso Directive) focuses on the environment (e.g. people, properties) whereas the ATEX Directive focuses on workers. Both are concerned with effects of explosions.

A risk assessment carried out within the scope of the Seveso Directive would consider and evaluate the effects (e.g. thermal, overpressure, fragments) of an explosion on the surroundings of the industrial site. If these effects turned out to be unacceptable, mitigation measures (organisational and technical barriers) will be amended. Among those, explosion venting of a premises can be decided so as to control missile effects.

Such a conclusion would neither be suitable nor sufficient for an ATEX Directive approach. Indeed, this measure does not evolve from a health and safety at work risk assessment. The venting of the premises does not in any way prevent workers from being injured or killed.

A more appropriate approach in line with the ATEX 1999/92/EC Directive philosophy would rather lead to the reduction of ATEX volume and therefore potential damages.

There are real differences between the objectives of Directive 1999/92/EC and Directive 96/82/EC. Employers must not be mistaken. Implementing the first one does not mean that expectations of the second one are satisfied. Both approaches have to be implemented.

Conclusion

For implementation of Directive 1999/92/EC, employers have to evaluate the volume of places where ATEX can occur as well as effects triggered by the ATEX ignition.

In order to perform an evaluation as accurately as possible, it is necessary to take into account real phenomena, which are involved in the generation of ATEX. By doing so, it makes it easier to take advantage of the first preliminary note of annex I of the Directive, which states that 'a place in which an ATEX is not expected to occur in such quantities as to require special precautions is deemed to be non-hazardous within the meaning of this Directive'.

Finally it may not be safe nor appropriate to oversize ATEX zones.

What seems to be safe and relevant consists of:

- first, taking prevention measures, in order to minimize or clear ATEX zones;
- then, taking mitigation measures, dedicated to prevent ignition sources and to protect workers from harmful effects of explosions occurring in ATEX zones.

References

1. Directive 1999/92/EC of the European Parliament and of the Council of 16 December 1999, on minimum requirements for improving the safety and health protection of workers potentially at risk from explosive atmospheres (15th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC).
2. PrEN 12981: 2000, Coating plants - Spray booths for application of organic powder coating material - Safety requirements.
3. Directive 96/82/EC of the European Parliament and the Council of 9 December 1996, on the control of major-accident hazards involving dangerous substances.